C0 Interaction Region (WBS 2.0)

Mike Church (WBS 2.0)

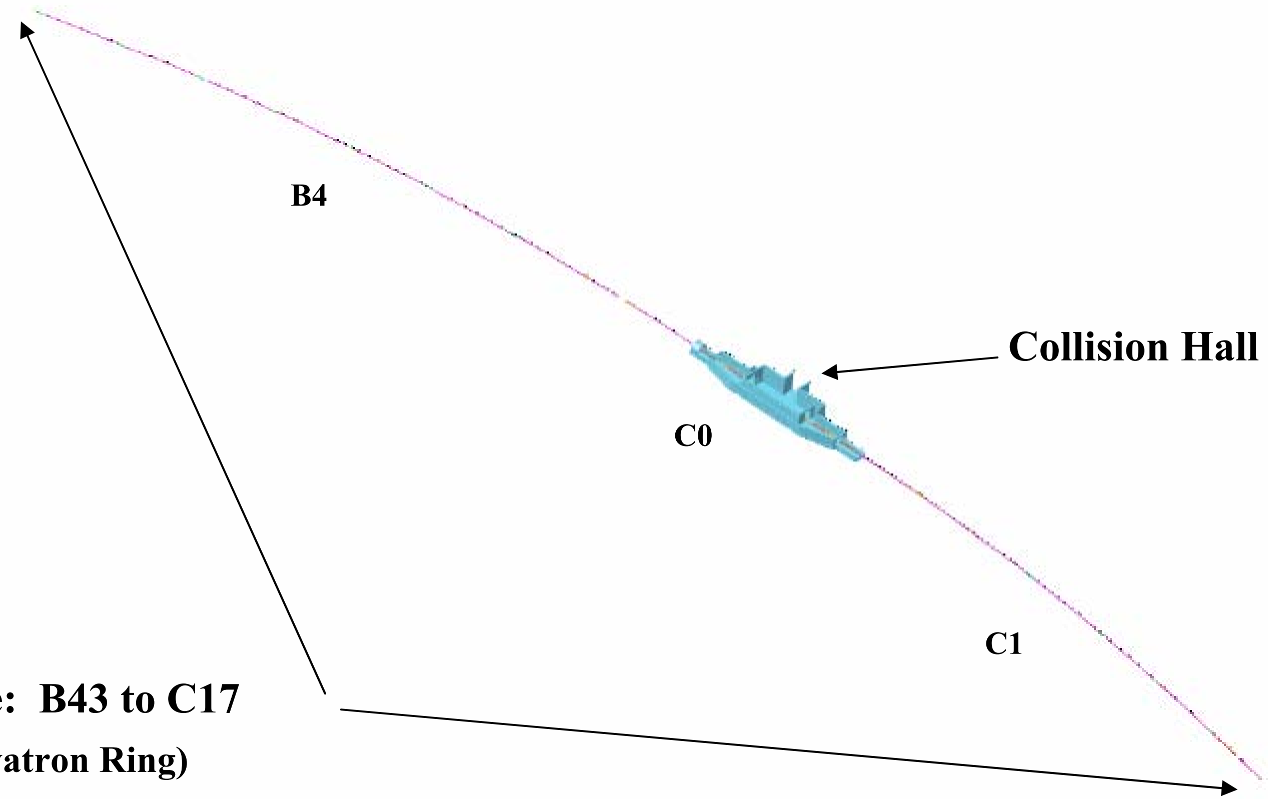
Overview

- Introduction
- Technical components
- Cost and Schedule
- Project flow, critical path, and risk analysis
- Breakout talks
- Glossary of terms

Requirements

- Provide an interaction region at C0 with $\beta^* < 50$ cm
- Support luminosity of >1E32 $cm^{-2}sec^{-1}$
- Keep magnetic components clear of C0 Collision Hall
- Maintain capability of running CDF and D0 experiments
- Complete installation in the 2009 Summer shutdown
- Reuse as much Tevatron infrastructure as possible

Tevatron C0 Region



Tevatron beamline: B43 to C17

(445 m, 7% of Tevatron Ring)

+ B4, C0, C1 service building installations
+ remove 4 magnets @A4/B1
+ move collimators
+ modify a few corrector circuits
- C0 collision hall (after 2005)

C0 IR Major Technical Components

- New LHC-type quadrupole magnets (10 installed)
- New spools (10 installed)
  - "spool" == corrector magnets, power leads, safety leads, …..
- Electrostatic separators (6 installed)
- Power supplies
- Nonmagnetic cryogenic elements
  - cryogenic bypasses, cryogenic spacers, "turnaround" cans, ….
- Infrastructure modifications
  - cryogenic headers, shielding, controls, software, operations, ….

- Installation in 2005, 2007, 2008, 2009 Summer shutdowns

Organization

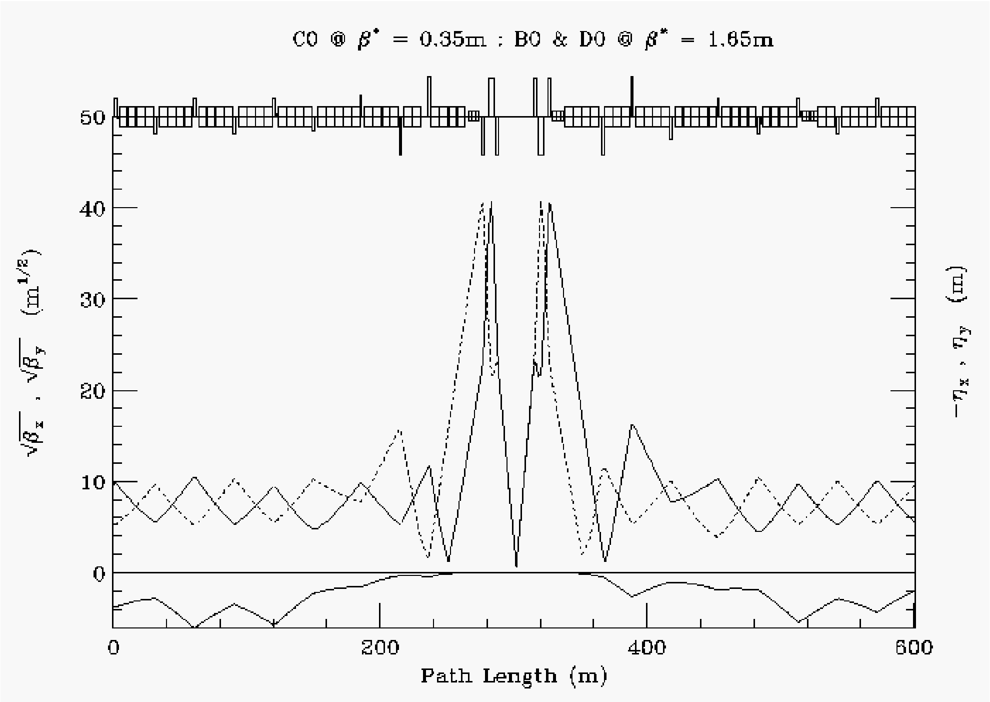
Base cost: $25.9M (Material: $13.1M, Labor: $12.8M)

- **WBS 2.0** – M. Church
  - **WBS 2.1** magnets – J. Kerby
    - **WBS 2.1.1** low beta quadrupoles
    - **WBS 2.1.2** new spools
    - **WBS 2.1.3** magnet management
  - **WBS 2.2** 2005 shutdown – P. Garbincius
  - **WBS 2.3** power supplies – G. Krafczyk
  - **WBS 2.4** cryogenics – J. Theilacker
  - **WBS 2.5** controls – S. Lackey
  - **WBS 2.6** instrumentation – R. Thurman-Keup
  - **WBS 2.7** separators – R. Bossert
  - **WBS 2.8** 2008 shutdown – R Reilly
  - **WBS 2.9** 2006 shutdown – R. Reilly
  - **WBS 2.10** 2007 shutdown – R. Reilly
  - **WBS 2.11** 2009 shutdown – R. Reilly
  - **WBS 2.12** hardware commissioning – G. Annala
  - **WBS 2.13** management + acc. physics – M. Church, P. Garbincius, J Johnstone

Lattice

Features:

- **35 cm β^***
- **Insertion adds 1 unit tune in each plane**
- **Insertion is optically matched to the rest of Tevatron at all stages of operation**
- **Magnetic elements stay outside C0 collision hall**
- **Two modes of operation:**
  - **collisions @ C0 or**
  - **collisions @ B0 and D0**



C0 collision lattice

The lattice design is mature, and any future modifications are on the level of fine tuning.

Beam Halo

Scenario	n	$h^{\pm}$	$e^{\pm}$	γ	$\mu^{\pm}$
No B48, no wall	24.2	14.5	58.9	1147	2.80
B48, no wall	11.0	9.29	42.4	730	1.81
B48, 2m wall	6.29	2.48	7.55	132	1.00

10^5 particles/sec entering collision hall (R<3.5m)

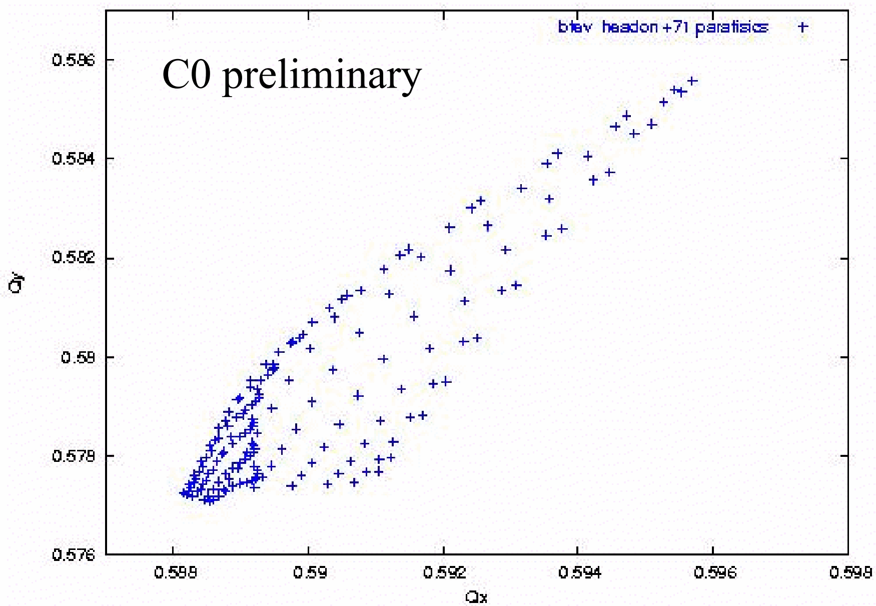
Source	D0	B0	C0
Nuclear elastic beam-gas	8.8	8.0	9.4
Large angle Coulomb beam-gas	0.12	0.06	0.1
Tails from collimators	2.4	3.5	0.99
Elastic p-pbar at two IP's	0.144	0.105	-

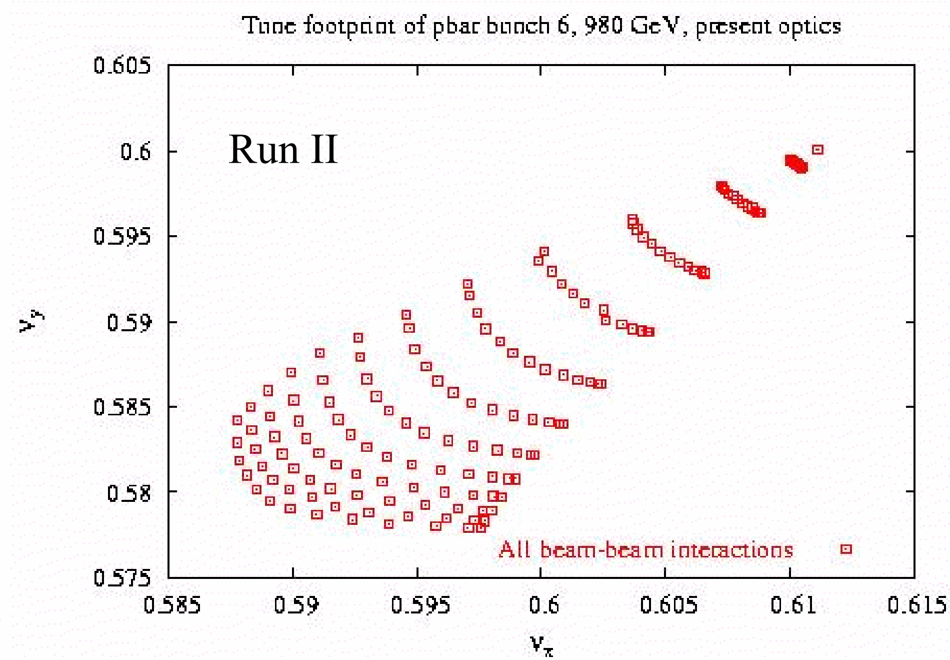
beam loss rates (10^4/sec) u.s. and d.s. of IP's

Beam halo calculations have been completed. Background rates are reduced a factor of ~10 with shielding and new collimator.

Tune Footprints

Antiproton bunch #6 tune footprint with 270E9 protons.





$\Delta\nu_x$=.008 $\Delta\nu_y$=.009

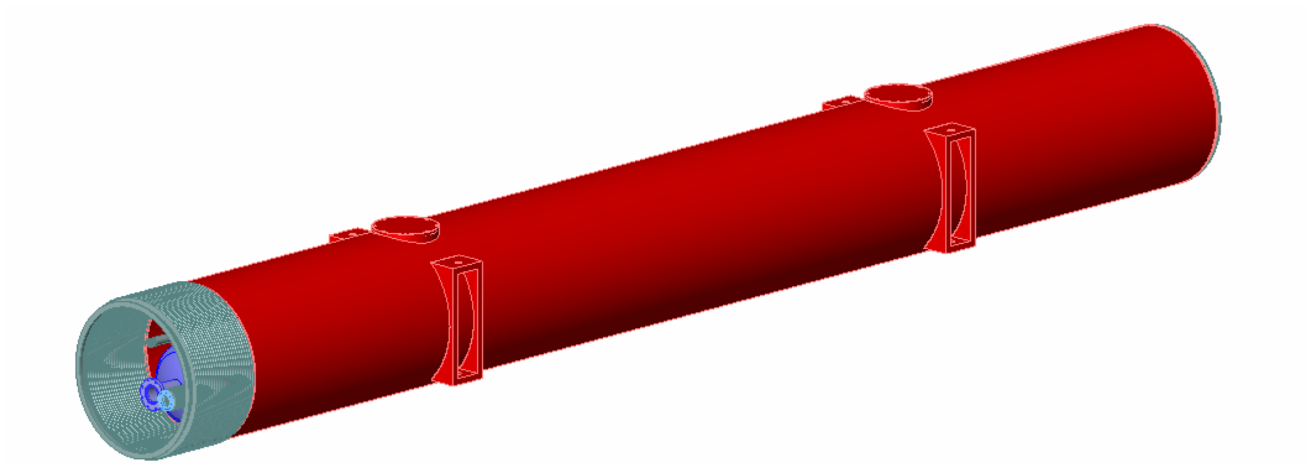
$\Delta\nu_x$=.023 $\Delta\nu_y$=.023

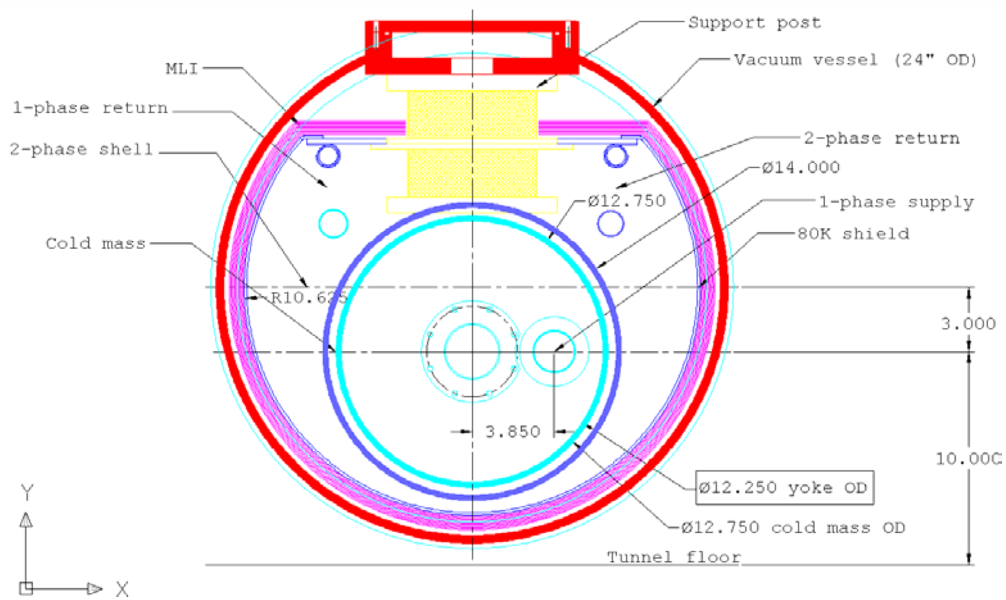
Dynamic aperture and tune footprint calculations are in progress.

Low Beta Quads

Features:

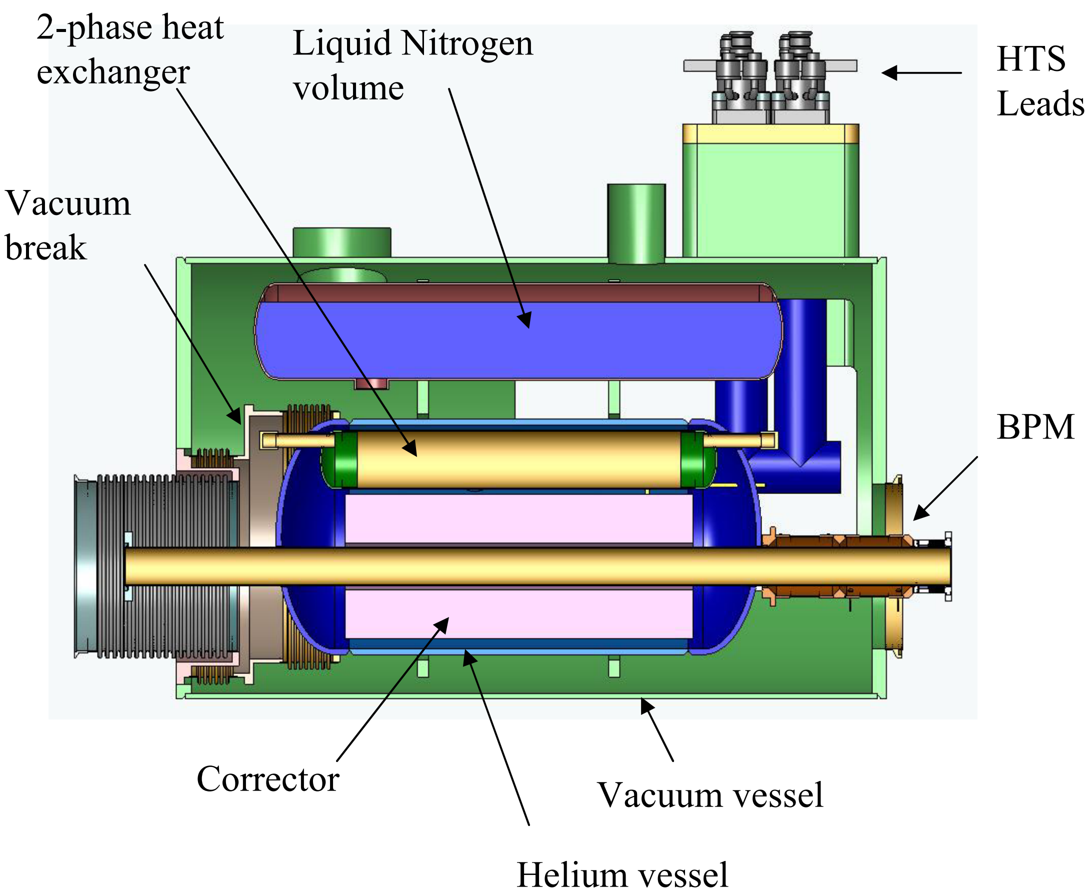
- Modified LHC design – cold mass is nearly identical; cryostat is redesigned to fit into the Tevatron tunnel
- Length varies from 1.4m to 4.4m
- Required current is 9560A
- 10 magnets to be installed: 2 x (Q1-Q5)





Spools

- 10 spools to be installed (5 types)
- Corrector packages contain V dipole, H dipole, quad, skew quad, or sextupole coils
- 10KA HTS leads provide power to adjacent quadrupoles

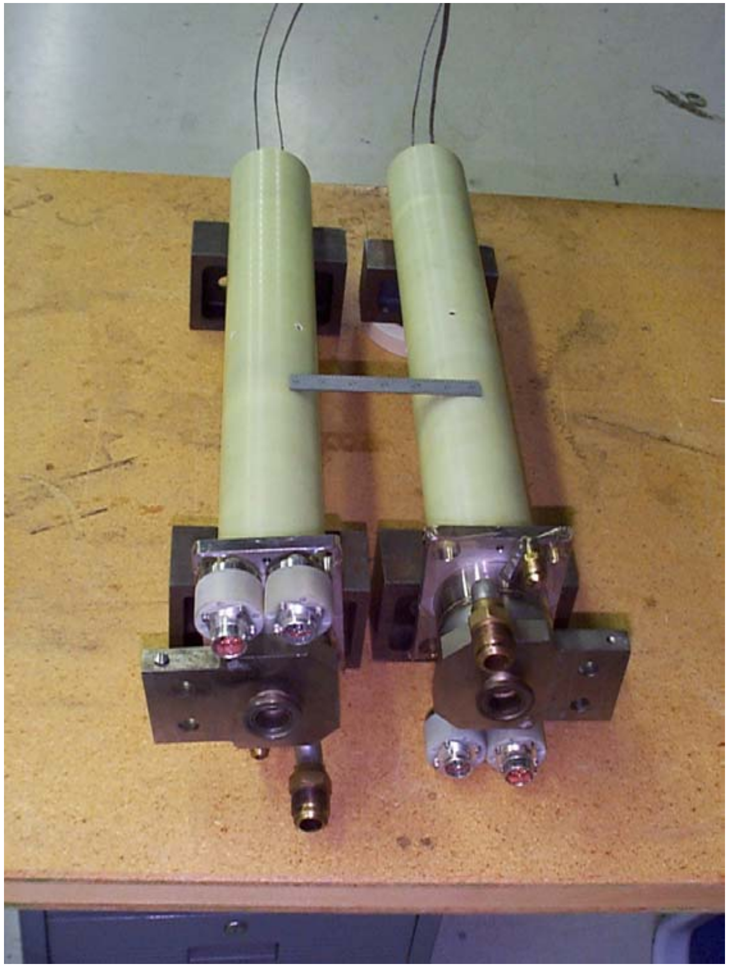


X2 spool

HTS Leads

- 6KA lead pairs have been used in the Tevatron for ~3 years
- Baseline proposal is to use 2 of these lead pairs in parallel to provide 10KA current capability
- We have successfully tested one of these lead pairs to 9.5KA; further tests may convince us that these leads will operate reliably at 10KA; this would reduce the cost for this item by almost a factor of 2
- We are investigating other possibilities (LHC leads, design modifications to the present leads, …)

American Superconductor Co



Corrector Magnets

		Corrector Magnets					
Spool	**Slot Length, m**	**VD T. m**	**HD T. m**	**SQ T.m/m**	**Sx T.m/m2**	**Q* T.m/m**	**Total per Spool**
X1V	1.83	**0.48**	*(0.48)*		**450**	**25**	**3**
X1H	1.83	*(0.48)*	**0.48**		**450**	**25**	**3**
X2L	1.43	**0.48**	**0.48**				**2**
X2R	1.43	**0.48**	**0.48**				**2**
X3	1.43	**0.48**	**0.48**	**7.5**			**3**
X3	1.43	**0.48**	**0.48**	**7.5**			**3**
X2R	1.43	**0.48**	**0.48**				**2**
X2L	1.43	**0.48**	**0.48**				**2**
X1V	1.83	**0.48**	*(0.48)*		**450**	**25**	**3**
X1H	1.83	*(0.48)*	**0.48**		**450**	**25**	**3**

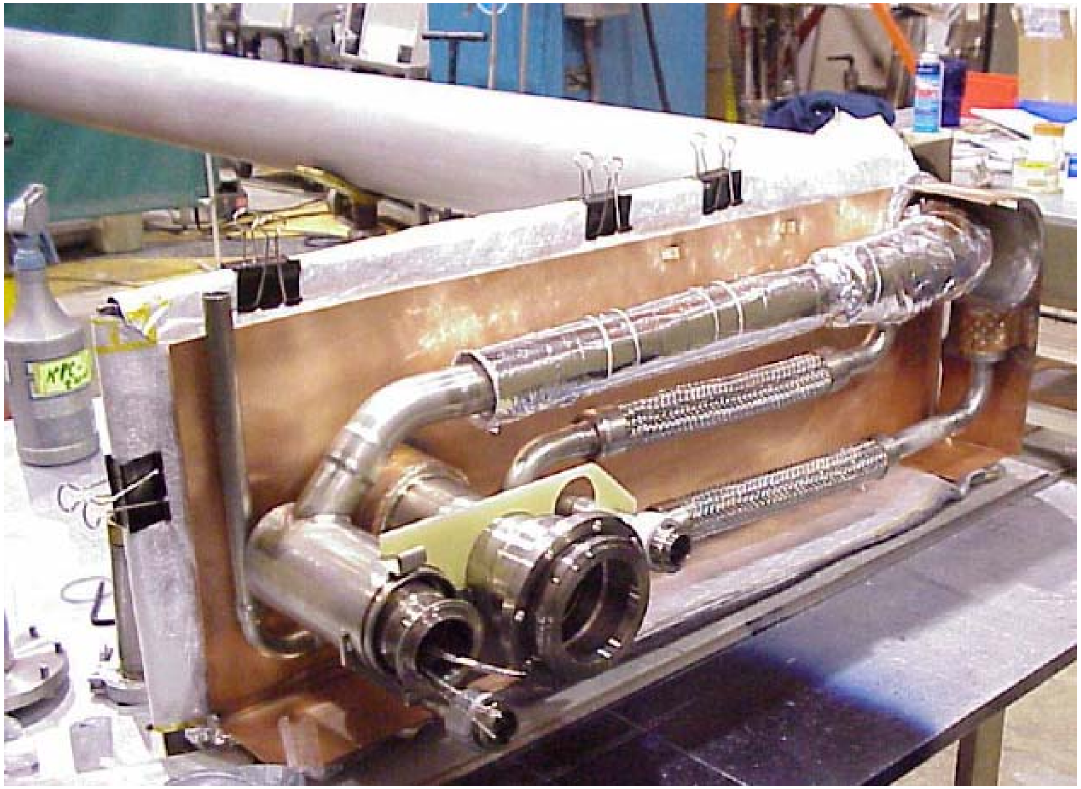
- Several design options are being explored
  - BNL "serpentine" design
  - Protvino multiple layer design
  - FNAL single layer design

Nonmagnetic Cryogenic Elements

10 new nonmagnetic cryogenic elements will be installed for the C0 IR project: warm bypasses, spacers, "turnaround" cans

These elements house cryogenic piping for helium and nitrogen, and carry superconducting cable for the main Tevatron bus.

Modifications to the Tevatron helium and nitrogen headers will also be made in order to make room for the new magnets.



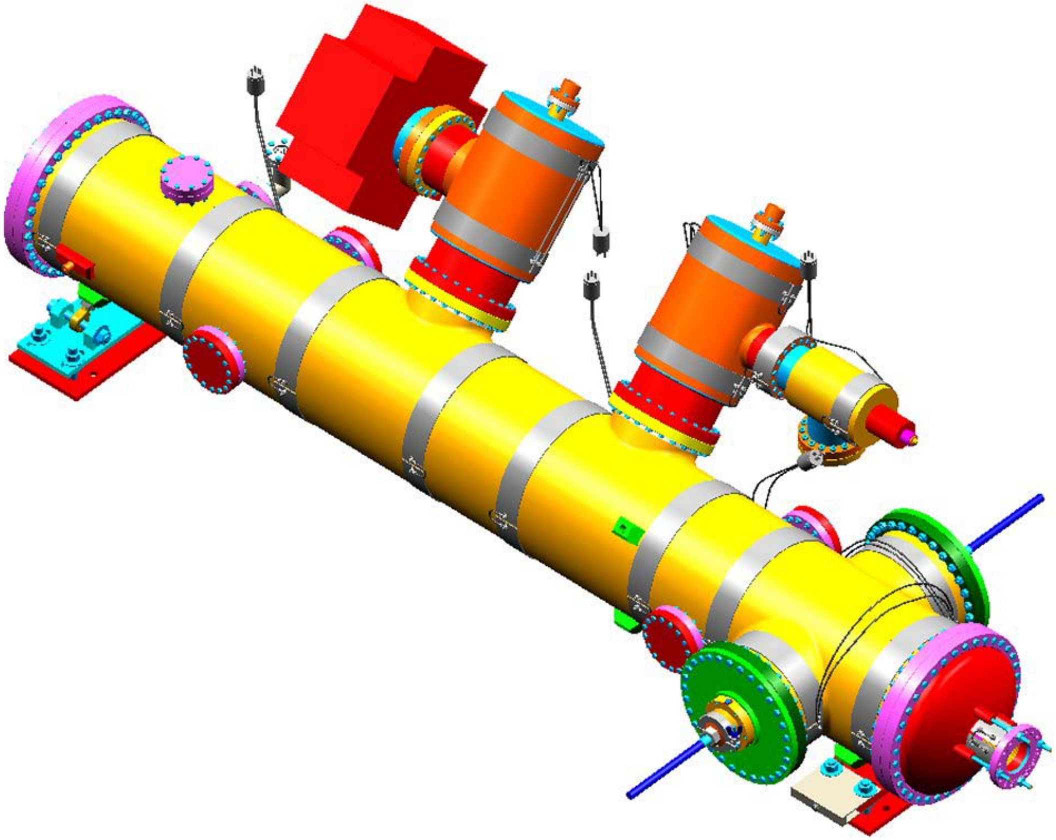
Electrostatic Separators

6 electrostatic separators will be installed for the C0 IR project.

These separate the proton and antiproton beams onto helical orbits.

These are identical in design to the separators currently in use in the Tevatron. Currently new separators are being fabricated and tested as part of the Run II upgrades.

Power supplies and polarity switches will also be built as part of this project.



Power Supplies

In addition to separator power supplies, the following power supplies are required:

- 3 10KA supplies for LHC-type quadrupoles
  - Similar to successful MI design, but with lower voltage
- 4 5KA supplies for reused Tevatron Q1 quads
  - Similar to successful MI design, but with lower voltage
- 2 200A shunts for LHC-type Q2 quadrupoles
  - Based on recent design for MI dipoles installed @ C0
- 13 50A supplies for the corrector magnets
  - Similar to MI design, but with additional quench detection circuitry

2005 Shutdown

The C0 straight section must be reconfigured to allow staged installation of the BTeV detector.

Currently the Tevatron uses MI dipoles to complete the bend at C0. These extend into the C0 collision hall.

These will be removed and full length Tevatron dipoles will replace the half-length dipoles currently in B4 and C1.

2006 – 2009 Shutdowns

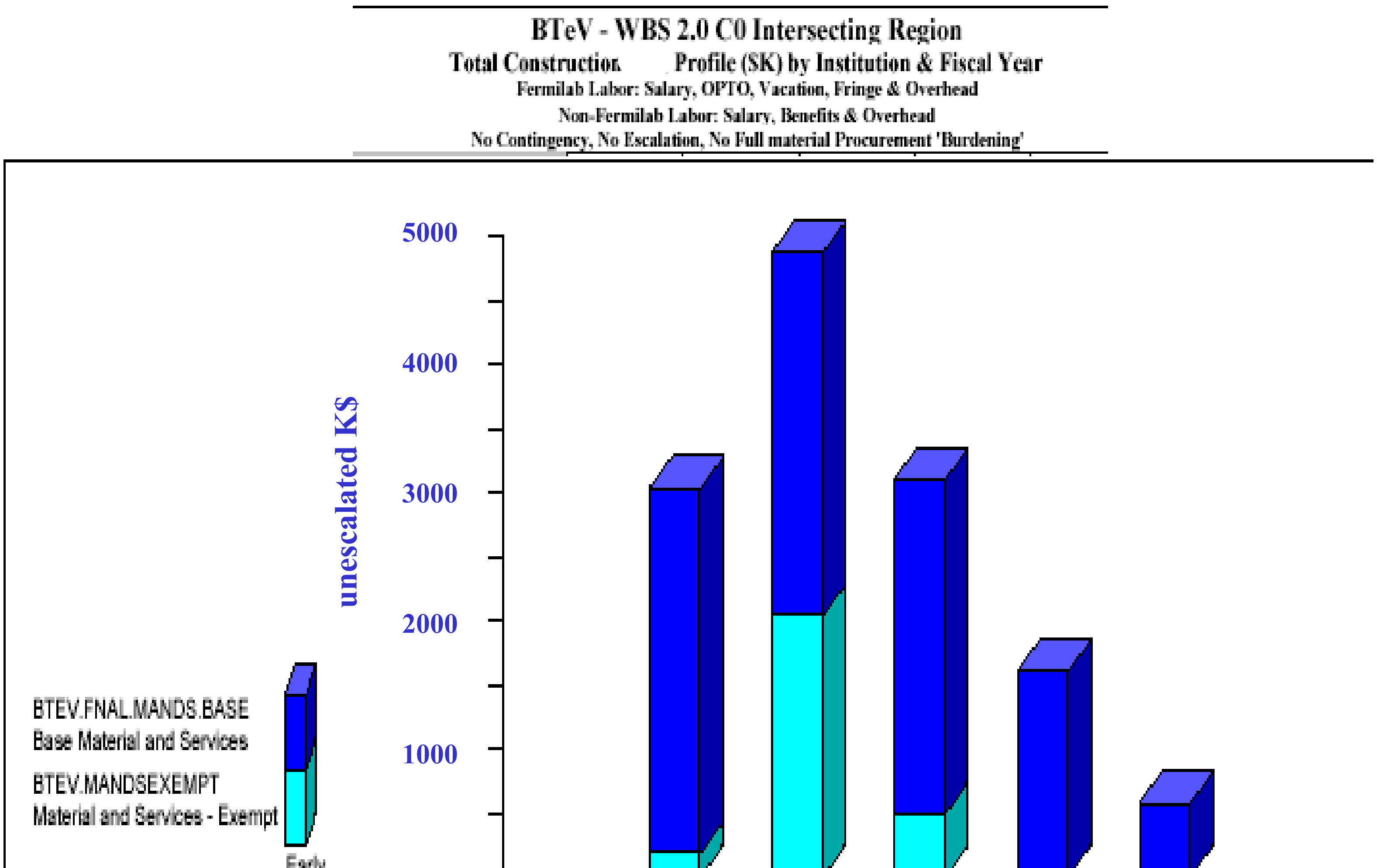
- 2006 shutdown
  - no work currently planned
- 2007 shutdown
  - LCW (Low Conductivity Water) and buswork installation
- 2008 shutdown
  - LCW and buswork installation continued
  - Removal of Q1s and P-spools from A4 and B1
- 2009 shutdown – 4 month duration
  - Full installation of C0 IR components
  - Almost all devices between B43 and C17 get moved or replaced
    - Move 23 dipoles, install 28 quads/spools, 8 cryogenic devices, 6 separators, 2 shield walls, 2 collimators, make cryo header modifications

Construction Cost

Base cost: $25.9M (Material: $13.1M, Labor: $12.8M)

Activity ID	Activity Name	Base Cost ($)	Material Contingency(%)	Labor Contingency(%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY05-09
2.1	New magnet fabrication and test	17,082,166	38	40	6,428,287	9,688,367	4,015,679	2,802,712	841,379	23,776,425
2.2	2005 shutdown	591,241	40	40	809,969	16,641	0	0	0	826,611
2.3	Power supplies	2,523,793	40	40	0	0	2,227,239	1,306,071	0	3,533,310
2.4	Cryogenic systems	1,395,397	27	39	0	301,788	690,082	902,234	0	1,894,104
2.5	Controls	495,638	45	23	0	0	331,092	77,784	236,462	645,338
2.6	Instrumentation	160,689	40	40	224,964	0	0	0	0	224,964
2.7	Electrostatic separators	724,803	40	40	0	0	605,874	374,868	33,983	1,014,724
2.8	2008 Shutdown	646,267	40	34	0	0	0	894,376	0	894,376
2.10	2007 Shutdown	454,836	40	40	0	0	631,114	5,656	0	636,770
2.11	2009 shutdown	1,825,988	40	40	0	0	0	178,493	2,378,940	2,557,433
2.12	Hardware commissioning	38,993	0	40	0	0	0	0	54,590	54,590
2	Subproject 2.0	25,939,811	39	39	7,463,221	10,006,797	8,501,080	6,542,194	3,545,354	36,058,645

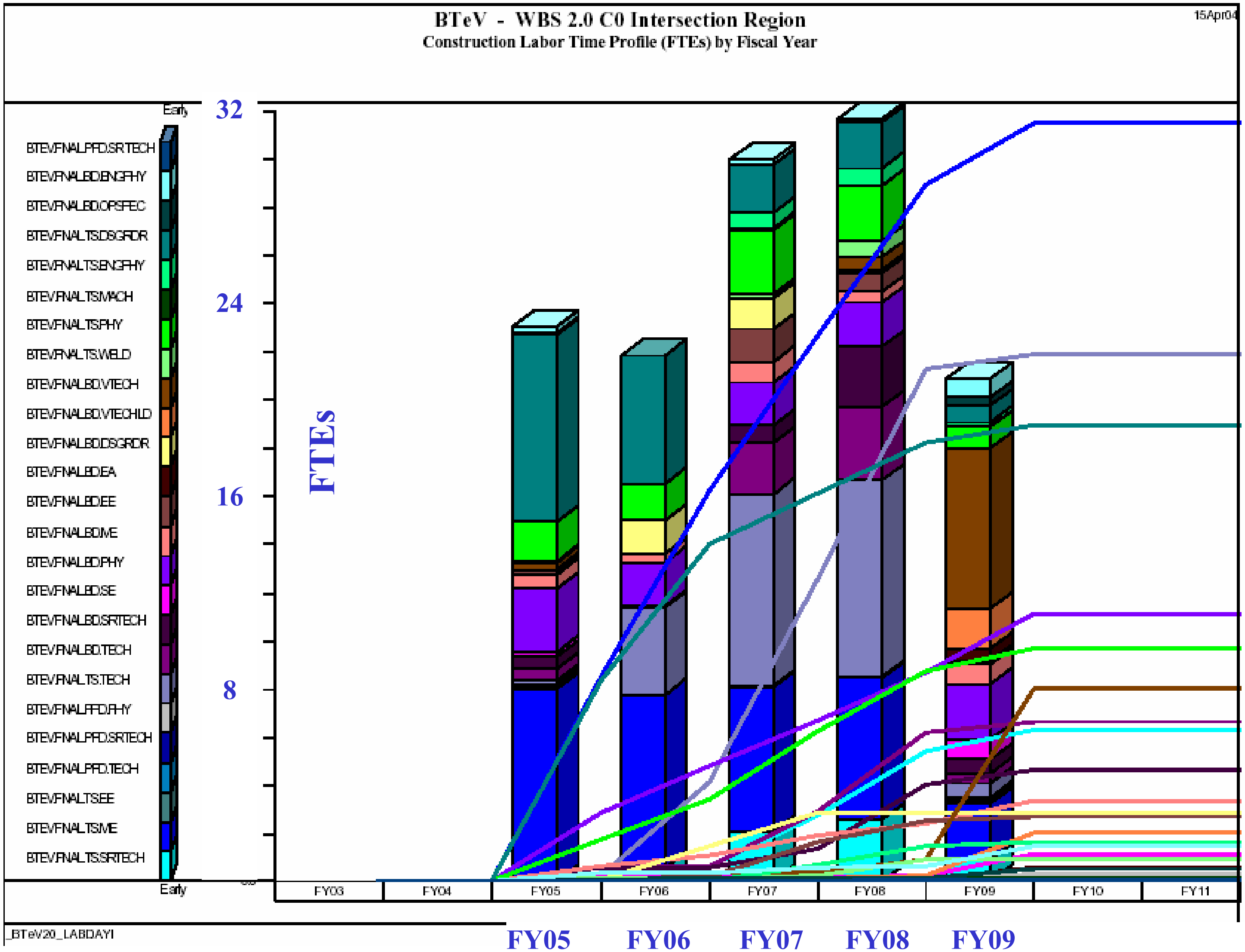
M&S Obligation Profile by Fiscal Year



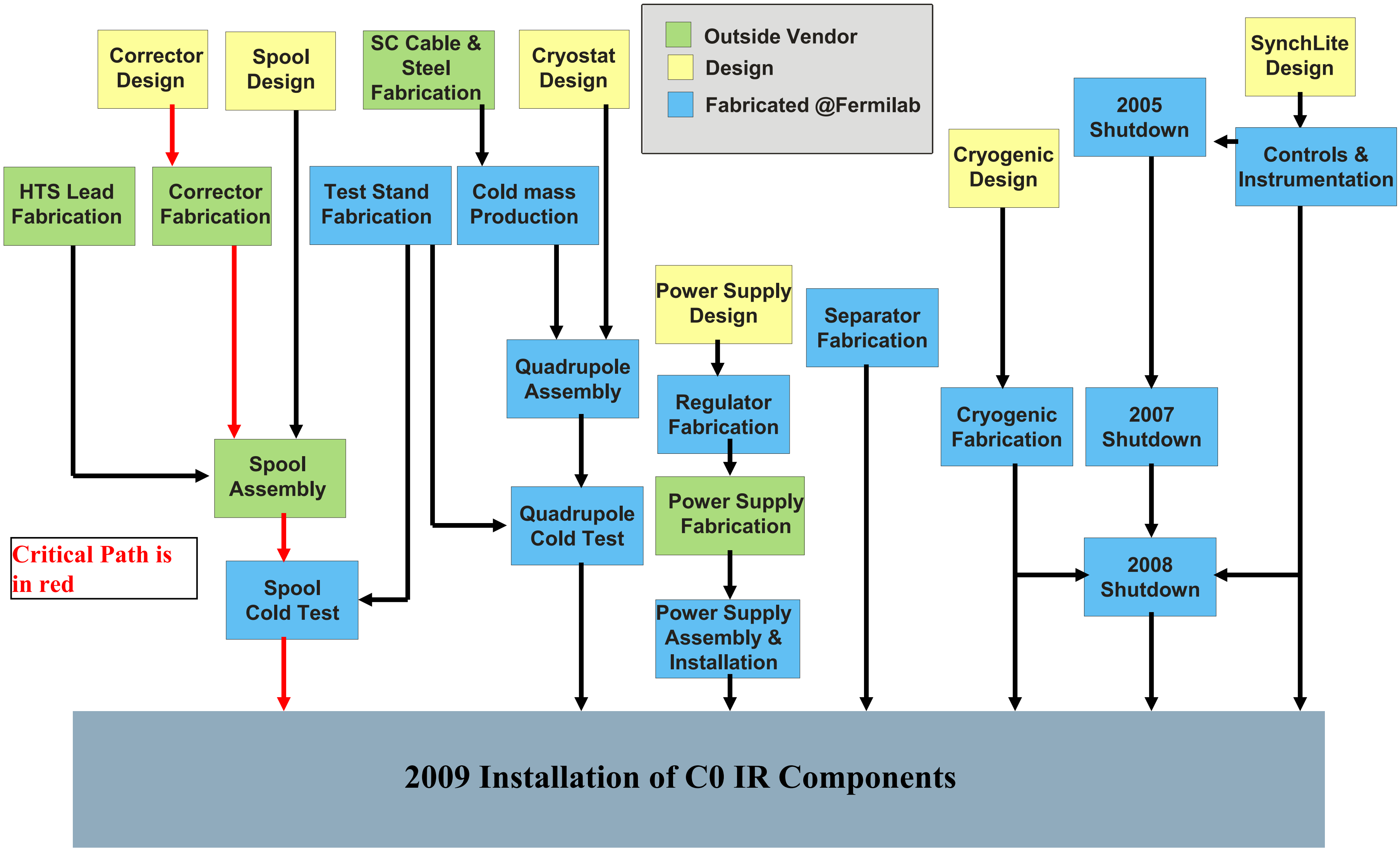
BTEV.MANDSEXEMPT : Material and Services - Exempt	0.0	179.2	2034.9	473.9	0.0	0.0	0.0
BTEV.FNAL.MANDS.BASE : Base Material and Services	0.0	2846.1	2819.1	2619.1	1598.4	563.9	0.0

FY05 FY06 FY07 FY08 FY09

Labor Profile by Fiscal Year



Project Flow



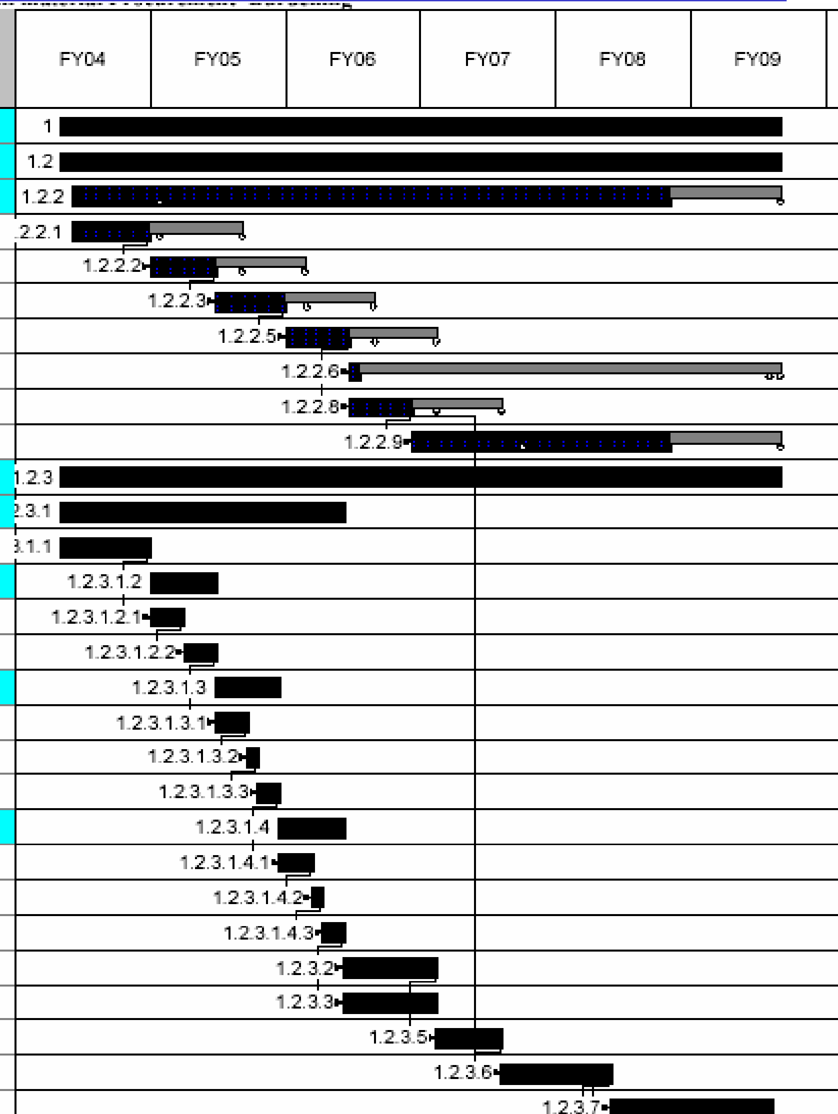
Key Milestones

- Initiate procurement of superconducting wire (10/04)
- Initiate procurement of HTS leads (1/05)
- Initiate procurement of corrector magnets (4/05)
- Begin quadrupole production (5/06)
- Begin spool assembly (5/07)
- Complete quadrupole fabrication and test (2/09)
- Complete spool fabrication and test (5/09)

(RED items are on critical path)

Critical Path

Activity ID	Activity Description	Duration	Start	Finish
1	New magnet fabrication and test	1347d	02Feb04	01Jun09
1.2	New Spools	1347d	02Feb04	01Jun09
1.2.2	CORRECTOR MAGNETS	1122d	01Mar04	05Aug08
1.2.2.1	Corrector Magnet Design Selection	151d	01Mar04	30Sep04
1.2.2.2	Corrector Magnet Final Design and Detailing	120d	01Oct04	28Mar05
1.2.2.3	Bidding Process	131d	29Mar05	30Sep05
1.2.2.5	Contract Evaluation	120d	03Oct05	21Mar06
1.2.2.6	Option to buy 2nd Batch	20d	22Mar06	18Apr06
1.2.2.8	Prototype Fabrication & Test	120d	22Mar06	08Sep06
1.2.2.9	Final Production Oversight	480d	11Sep06	05Aug08
1.2.3	SPOOL ASSEMBLY	1347d	02Feb04	01Jun09
1.2.3.1	Spool Design	531d	02Feb04	06Mar06
1.2.3.1.1	Conceptual Design	171d	02Feb04	30Sep04
1.2.3.1.2	X1 Design	120d	01Oct04	28Mar05
1.2.3.1.2.1	Helium Vessel	60d	01Oct04	29Dec04
1.2.3.1.2.2	Vacuum Vessel	60d	30Dec04	28Mar05
1.2.3.1.3	X2 Design	120d	29Mar05	15Sep05
1.2.3.1.3.1	Helium Vessel	60d	29Mar05	21Jun05
1.2.3.1.3.2	LN2 System	20d	22Jun05	20Jul05
1.2.3.1.3.3	Vacuum Vessel	40d	21Jul05	15Sep05
1.2.3.1.4	X3 Design	120d	16Sep05	06Mar06
1.2.3.1.4.1	Helium Vessel	60d	16Sep05	12Dec05
1.2.3.1.4.2	LN2 System	20d	13Dec05	09Jan06
1.2.3.1.4.3	Vacuum Vessel	40d	10Jan06	06Mar06
1.2.3.2	Bidding Process	180d	07Mar06	16Nov06
1.2.3.3	Bidding Process (with EXEMPT M&S)	180d	07Mar06	16Nov06
1.2.3.5	Contract Evaluation	120d	17Nov06	10May07
1.2.3.6	Prototype Fabrication & Test	200d	11May07	28Feb08
1.2.3.7	Final Production Oversight	300d	29Feb08	07May09



Critical Path Analysis

- Corrector magnets (installed in spools):
  - design finalization → contractual process → fabrication
  - Completion of fabrication preceeds spool assembly completion by ~9 months
  - Fabrication estimates based on subset of LHC corrector experience
- Spool assembly:
  - design → contractual process → assembly → cold-testing
  - Fabrication estimates based on LHC DFBX experience
    - DFBX is LHC cryogenic feedbox of similar complexity
  - HTS leads are also assembled in spools, but there is available float on this item

There exists some additional float if we are willing to assume that the last spare does not need to become available until the end of the 2009 shutdown.

Risk Analysis

- Risks
  - Superconducting cable procurement →
  - HTS lead procurement →
  - Corrector magnet contract →
  - Spool assembly contract →

- Mitigation
  - Issue RFP by 10/04
  - Requires proposed funding profile

  - Continue discussions with vendors
  - Issue RFP by 1/05
  - Requires proposed funding profile

  - Continue investigation of procurement options
  - Issue RFP by 3/05
  - Requires proposed funding profile

  - Continue investigation of vendor options
  - Issue RFP by FY06

(RFP == "Request for Proposal")

Early Long Lead Time Items

- Superconducting wire ($0.80M)
  - RFP by 10/04; 1st delivery required by 5/06
- HTS leads ($0.83M)
  - RFP by 1/05; 1st delivery required by 8/06
- Corrector magnets ($0.71M$)
  - RFP by 4/05; 1st delivery required by 9/06
- Quadrupole collar steel ($0.11M)
  - RFP by 9/05; 1st delivery required by 7/06

(RED item is on critical path; $$ are M&S, with G&A, no contingency, spares not included)

Breakout Talks

More detailed information is available in the breakout sessions.

- Accelerator Physics – John Johnstone (4 PM today)
- Quadrupole Cold Mass – Fred Nobrega (starting 8 AM tomorrow)
- Quadrupole Cryostat – Tom Nicol
- Spools – Tom Page
- HTS Leads – Sandor Feher
- Corrector Magnets – John Tompkins
- Magnet Cost Overview – Deepak Chichili
- 2005 Shutdown – Peter Garbincius
- Power Supplies – George Krafczyk
- Electrostatic Separators – Rodger Bossert
- Cryogenic Elements – Jay Theilacker
- Controls – Sharon Lackey
- 2007 – 2009 Shutdowns – Rob Reilly

Glossary

- **β*:** beta function at the interaction region; luminosity is inversely proportional to this quantity
- **Spool:** cryogenic element that contains corrector magnets, power leads, safety leads, quench stoppers, relief valves, and other items not contained in main magnets
- **HTS lead:** High Temperature Superconductor power lead; transfers magnet power from external warm bus to superconducting cable within cryostat
- **RFP:** Request for Proposal; this initiates the formal procurement process
- **DFBX:** LHC cryogenic feedbox; used as basis of estimates for spool assembly
- **LCW:** Low Conductivy Water; used to cool magnets, power supplies, and power leads
- **Tevatron locations:** Tevatron is divided into 6 major sectors, A – F; each sector has a long warm straight section, A0 – F0; each sector is divided into 4 cryogenic houses, A1 – A4, …, F1 – F4